ELECTRICAL PROTECTION OF AERIAL CABLE

CONTENTS

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors, and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. This section discusses in particular the principles involved in the electrical protection of aerial cable and details of the application of arresters. It describes the normal methods for protecting aerial circuits from lightning and power contacts by means of arresters, shield grounding, and shield bonding. In unusual situations these measures may need to be supplemented as discussed in REA TE & CM-825.

1.2 This section replaces Section 815, Issue 3, dated October 1960. The principal changes involve the eliminat
and a general updating of the informatior on the
plastic cable.

1.3 For the purpose of this section
group of insulated conductors e
a plastic jacket with one or more met
and jacket. Except where qualified,
and refers to plastic-jacketed cable
insulated conductors and lead-sheath
insulated conductors. Plastic-jacket
conductors is sometimes referred to a
refers to the metallic envelope surro
wise indicated. The terms "jacket" a
and refer to the nonmetallic outer co
types of cables.

[illegible] coaxial cables are not included in this [illegible]

[illegible] POTENTIALS

[illegible] - Lightning is a transient discharge between a charged [illegible] the earth or another cloud, involving currents upwards [illegible] and usually lasting a few hundred microseconds. [illegible] in cable plant may occasionally arise due to direct [illegible] or to the cable itself. If an appreciable portion [illegible] lightning stroke is carried by elements of telephone cable [illegible] protective measures against damage are usually not [illegible] commonly, lightning disturbances appear in cable [illegible] from connecting open wire or distribution wire, by [illegible] nearby strokes to earth, by conduction from the earth [illegible] stroke point to the cable through guys or pole grounding [illegible] to rise in ground potential at nearby grounded points such [illegible] tectors. If adequate protective measures are not taken, [illegible] charges may result in breakdown of the insulating materials [illegible] conductors and the grounded metallic cable shields or between [illegible] themselves. The effect of dielectric failure on service [illegible] depend on the magnitude and duration of the surge and the sus- [illegible] of the materials involved to permanent damage, such as melting [illegible] conductor and its insulation or carbonization of the conductor [illegible].

In addition to the problem of dielectric failure discussed above, excessive lightning surge currents can cause fusing of the conductors. The use of plastic insulation has increased the dielectric strength of cable conductors to the point where dielectric failure seldom occurs. This causes the current surges to flow through the conductors rather than being by-passed through conductor insulation. The use of fine gauge conductors reduces the surge current carrying ability of typical cables as compared with cables formerly used. As a result of these two factors, lightning damage to modern plastic cable plant is more likely to be caused by conductor fusing rather than from dielectric failure.

2.2 Power Contacts - Association of telephone cable (or wire) facilities with power distribution circuits, as a result of the joint use of poles or at crossings, involves hazards incidental to electrical contact between these systems. Such contacts usually take place under the severe mechanical stresses produced by high wind, heavy ice, snow loads, or combinations of these factors. Although the currents developed in cable plant as a result of such contacts are likely to be in the order of hundreds rather than thousands of amperes, their duration is in the order of seconds rather than microseconds. Consequently, power contacts are likely to subject the telephone plant to heating and burning effects, as well as to dielectric stress. However, the frequency of occurrences of power contacts is much smaller than that of lightning interference. Power contacts

with metal shielded cable and strand may burn the cable down due to arcing effects, and power current in cable conductors may result in fusing of these wires. In the event of a power contact to strand supported plastic-jacketed cable, although the dielectric strength of the insulating jacket will ordinarily be high enough to prevent breakdown to the metal shield, contact to the cable strand and/or lashing wire may produce sufficient arcing to melt the plastic jacket and result in damage to cable pairs, or possible burndown.

3. PROTECTION PRINCIPLES

3.1 Lightning Protection

3.11 Direct lightning strokes to cable plant are likely to cause extensive damage due to the magnitude of the currents involved; however, such strokes occur very infrequently and are not a major source of trouble. Protection against direct strokes is impracticable.

3.12 Lightning surges may also reach the conductors and/or shield of aerial cable by currents conducted from non-cable plant*, by induction from nearby strokes to ground, and by currents developed due to rise in ground potential at stroke points near station protector installations. Cable having paper- or pulp-insulated conductors requires protective measures in the form of arresters against such potentials. Cable having plastic-insulated conductors does not require protective measures except in unusual circumstances as outlined in subsequent paragraphs.

3.13 In addition to the prevention of dielectric failure of the cable conductor insulation, it is essential that potential differences between all of the other conducting elements of the cable installation be avoided. This requires that the shields of all aerial cable sections be bonded together and to connecting underground or buried cable shields and to the central office ground. Cable support strands should be electrically continuous, and cable shields should be bonded to the support strands at appropriate intervals.

3.2 Power Contact Protection - The most effective measures in preventing power contacts to aerial cable or connecting plant are to follow standard construction practices and provide proper clearances in accordance with the provisions of REA TE & CM-602, "Clearances;" REA TE & CM-630, "Design of Aerial Cable Plant;" REA TE & CM-635, "Construction of Aerial Cable Plant;" and REA TE & CM-690, "Joint Use of Poles."

3.21 Important supplementary construction practices consist of providing low impedance paths to ground which will aid in rapid deenergization of the power line in the event of a power contact. Discussion of protective measures to be applied in the event of power contacts with connecting non-cable type conductors is covered in REA TE & CM-820, "Open Wire Circuit Protection," and REA TE & CM-821, "Multipair Distribution Wire Protection."

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*The term "non-cable plant" refers to conductor facilities such as open wire, distribution wire, and drop wire which are not enclosed in a metallic shield.

4. LIGHTNING PROTECTION CONSIDERATIONS FOR PLASTIC-INSULATED CONDUCTOR CABLE

The surge dielectric strength of cable employing plastic-insulated conductors* is conservatively considered for engineering design purposes as follows:

Gauge	Surge Dielectric Strength (Peak kv) Conductor to Conductor	Conductor to Shield
[illegible]	25	30
[illegible]	20	25
[illegible]	15	20
[illegible]	15	20

Cables having dielectric strengths of these magnitudes are essentially free from damage by lightning. The immunity of PIC cable without arresters (except in special circumstances) to lightning damage has been well established by experience in the Bell System over a period of many years.

4.02 The normal protection of -PIC cable in all areas should consist of the following items which are discussed in detail in subsequent paragraphs:

Bonding and grounding cable shields at the C.O.
Maintaining electrical continuity of the shields.
Bonding cable shields to support strands.
Termination of cable pairs on terminal blocks at
  open wire junctions.
Incidental grounding of cable shields at non-cable junctions.
Gas tubes or the equivalent at junctions with facilities serving
  severely exposed stations.
Protection against fusing of cable conductors.

4.03 Bonding and Grounding Cable Shields at the Central Office - The shields of all cables entering a C.O. should be bonded to each other and to the C.O. ground. This measure eliminates harmful differences of potential between the various cables entering the C.O.

4.04 Maintaining Electrical Continuity of Shields - It is important that electrical continuity of aerial cable shields be maintained and that such shields be bonded to any connecting buried or underground cable shields in order to provide a path to ground for lightning and power currents, and to provide an effective noise shield. The installation of ready-access enclosures and the application of cable splicing procedures as covered in REA Splicing Standard PC-2 will usually assure adequate bonding of shields from a protection standpoint.

*PE-22, "REA Specification for Fully Color Coded Polyethylene Insulated, Polyethylene Jacketed Telephone Cables."

4.05 Bonding Cable Shields to Support Strands - Cable shields should be bonded to the support strand at frequent intervals to prevent arcing and to provide a low impedance path to ground for foreign currents. With plastic-jacketed cable, bonds between the shield and strand should be provided at all splices, terminals, and loading points. The methods of bonding the shield to the strand depend on the types of enclosures used and are described in detail in PC-2* and PC-3**.

4.051 Four or more bonds per mile should be provided if possible without opening the plastic jacket solely for this purpose. Where long runs without splices, terminals, or load points are involved, at least one bond per mile should be provided even if it is necessary to open the cable sheath solely for this purpose. If more than one cable is attached to the same pole by means of separate through-bolts or separate mounting fixtures, the shields of the various cables should be bonded together (1) at crossing poles; (2) at the beginning and ending of multicable runs; and (3) at approximately 1500-foot intervals in long multicable runs.

4.06 Termination of Cable Pairs on Terminal Blocks at Open Wire Junctions - When one or more pairs are extended by open wire at a cable deadend, all pairs should be terminated on unprotected terminal blocks. Where one or more pairs are extended by open wire at a tap point along the cable, enough unprotected terminal blocks should be provided to terminate the pairs that are to be extended by open wire. The number of cable pairs terminated should equal the number of pairs of terminal studs installed.

4.061 It has been determined by tests that unprotected terminal blocks with normally spaced terminal studs equipped with nuts will break down under typical lightning surges at values below the surge dielectric strength of plastic cable and wire conductors. It is, therefc
to use the terminal studs on unprotected terminal blocks as
Effective protection against dielectric f
provided if all pairs in the cable at o
terminated on terminal blocks.

4.07 Incidental Grounding of Cable
Normal construction practices
strands at deadends and other junctio
sonnel protection, and/or power conta
beneficial in reducing lightning pote
voltage limiting gaps (such as termin
to the conductors. Grounds are also

*"REA Standard for Splicing and Termi
Cables Used on Telephone Systems of F
**"REA Standard for Straight Splicing
Sheathed Cables to Paper-Insulated Le
Systems of REA Borrowers."

...le conductors on lightning surges, by diverting a portion ... ground before it reaches the cable conductors. Grounds ... placed at other points on the shield unless required for ... protection (paragraph 6.1 or 6.2).

<u>... or the Equivalent at Junctions with Facilities Serving ... Exposed Stations</u> - At junctions with facilities of any ... serving stations that are unusually severely exposed to ... (such as fire towers and radio towers), it is recommended ... or greater breakdown gas tube arresters be installed on the ... between the conductors and the shield. An accepted alter... tubes would be to install yellow-coded (10 mil) gap carbon ...ers.

<u>Protection Against Fusing of Cable Conductors</u> - The probability of ... cable conductors can be minimized by providing conducting ... surge currents, which divert the incoming surges to the shield ... before they reach the cable conductors. The measures described ... 4.02 through 4.08 usually accomplish this.

<u>... Drops</u> - At points along aerial cable runs where service ... are connected, arresters for lightning protection are not required. Connections of drop wires to aerial cable conductors must be made so as to meet National Electrical Code (NEC) coordi... requirements for station protection. Connection details are shown ... Construction Drawings in the "Telephone System Construction Con... REA Form 511."

In addition to the above items, under unusually severe exposure conditions, supplementary protection measures may be needed. Details ... supplementary protection should be determined by the borrower's ... after a careful study and should be approved by REA.

...CATION OF LIGHTNING PROTECTION TO PAPER- OR PULP-INSULATED CABLE

The ... ...ing paper- or pulp-insulated con... ...e crest from core-to-shield and ...strokes to earth near connecting ...entials in excess of this value, ...tive measures are taken.

...-insulated cable are divided ...htning incidence and earth ...sed in the nonshaded areas ...ndicates a greater degree ... should be used in the ...nshaded areas if justified ...uld be used <u>only</u> in areas ... as defined in paragraph 5.5.

5.3 Category I - Category I lightning protection for paper-insulated cable consists of the following measures which are discussed in detail in other paragraphs:

Bonding and grounding cable shields at the C.O. (paragraph 4.3).
Maintaining electrical continuity of shields (paragraphs 4.4 and 5.31).
Bonding cable shields to support strands (paragraphs 4.5 and 5.32).
Installation of carbon block protectors at cable terminals, (paragraph 5.33).
Grounding of cable shields (paragraph 5.34).

5.31 Maintaining Electrical Continuity of Shields.

5.311 The importance of this measure is discussed in paragraph 4.4, and the procedure for paper-insulated cable having an outer plastic jacket is the same as given in paragraph 4.4 for PIC cable.

5.312 With lead-sheathed cable having lead sleeves and wiped joints, electrical shield continuity is assured incidental to splice closing.

5.32 Bonding Cable Shields to Support Strands.

5.321 This measure is discussed in paragraph 4.5, and the procedure for paper-insulated cable having an outer plastic jacket is the same as given in paragraph 4.5 for PIC cable.

5.322 With lashed lead-shielded cable an adequate bond is obtained incidentally by the lashing wire.

5.33 Installation of Carbon Block Protectors at Cable Terminals.

5.331 All cable pairs extended by non-cable type facilities more than about 1500 feet in length should be protected by the connection of carbon block arresters (blue designated) between the extended pairs and the cable shield at the junction of the cable and non-cable plant. Where one or more non-cable type pairs exceed about 1500 feet, all of the extended pairs connected to the same terminal, regardless of length, should be equipped with blue designated arresters. Use of a fully equipped protected type terminal will often furnish protection to pairs not extended by non-cable plant with beneficial results.

5.332 All cable pairs extended by PIC cable should be protected by providing arresters (blue designated) on all non-cable type extensions from the PIC cable that occur within 1 mile of the paper to PIC cable junction. In some instances it may be more economical to provide arresters (blue designated) on all pairs of the paper cable extended by PIC cable at the PIC-to-paper cable splice.

5.333 If the provision of arresters in accordance with paragraph 5.332 results in full count protection of the paper cable, the shield should be grounded at that point. If full count protection does not result, the ground should be omitted.

5.34 Grounding of Cable Shields - Installation of grounds at cable ends and at junctions with non-cable plant extending more than about 1500 feet will divert a portion of an incoming surge to ground and thereby reduce the magnitude of surge on the cable shield. If a ground resistance of 25 ohms or less can be obtained, about 50 percent of the incoming surge can be diverted. Grounds exceeding about 100 ohms will not reduce the surge on the shield appreciably. A MGN ground is often the lowest resistance d.c. or 60 Hz ground electrode available in rural areas, but it is not necessarily a low impedance to lightning surges. Even though it may not be an effective lightning ground, an MGN should be used if available for grounding cable shields at such junctions because it would be effective in deenergizing power contacts to the cable. (See subsection 6.) When it is not practicable to connect to a MGN ground and it is anticipated that a ground resistance of the order of 100 ohms or less is unlikely, omission of the shield ground would be indicated.

5.4 <u>Category II</u> - Category II lightning protection for paper-insulated cable consists of all Category I measures plus the following:

- Exclusive use of fully protected cable terminals (paragraph 5.41).
- Full count protection at cable ends (paragraph 5.42).
- Additional shield grounding at full count protection points (paragraph 5.43).

5.41 Exclusive Use of Fully Protected Cable Terminals - The probability of lightning damage to paper-insulated cable in Category II areas is great enough to justify exclusive use of fully protected cable terminals. This ensures that all pairs extended by non-cable facilities including drops will be protected. It will also result in multiple protection on pairs that appear in more than one cable terminal, and will provide protection on a large percentage of idle pairs.

5.42 Full Count Protection at Cable Ends - Full count protection should be provided at the outer ends of main and branch cable if any circuits are extended from these cable ends more than 1 mile by non-cable type facilities.

5.43 Shield Grounding at Full Count Protection Points - In general, because of the greater likelihood of damaging lightning surges in Category II areas, the provision of a shield ground of 25 ohms or less becomes more important. Measures such as trenching, use of an aerial ground wire to reach a MGN, the use of several ground rods in parallel, or the use of a sectional ground rod may be justified.

5.5 Category III - Category III lightning protection for paper-insulated cable is expensive to install and to maintain, and should be used only in unusually severe exposures and lightning damage areas. Such situations might arise by way of non-cable connections to fire towers or radio stations in areas of high lightning incidence and high earth resistivity. Category III protection of paper-insulated cable consists of all Category I and Category II measures plus the following additional measures:

Additional full count protection points.
Low impedance made grounds.

5.51 Additional Full Count Protection Points - In addition to full count protection at cable end points, full count protection should also be provided at intermediate junctions where six or more pairs are extended by non-cable plant for a distance greater than about 1 mile.

5.52 Low Impedance Made Grounds - If a MGN ground or a water pipe ground of 25 ohms or less is not available, a made ground consisting of driven ground-rods connected in parallel or a deep driven sectional ground rod should be provided at each full count protection point. The resistance of made grounds should not exceed 25 ohms.

6. BONDING AND GROUNDING FOR POWER CONTACT PROTECTION

6.1 Bonding at Power Crossings - Where practicable, crossings between aerial telephone cables and electric distribution lines of any type should be made on jointly used poles. At joint pole crossings with MGN type power lines, the cable support strand should be interconnected to the MGN via a vertical pole ground wire. Where it is not practicable to obtain joint pole crossings with electric distribution lines and for all aerial crossings with electric transmission lines, inspan crossings may be used. For all inspan crossings, protection of the telephone plant depends primarily on adequate structural strength and clearances, which in some cases may require putting the telephone plant in underground conduit or using buried cable, (see appropriate TE & CM for details).

6.2 Bonding in Joint Use

6.21 Where telephone cables are supported by the same poles used for electric supply circuits of the multigrounded neutral type, the cable shields and suspension strands should be bonded to the MGN as described in paragraph 6.24. These bonding connections should be made at the following locations:

(1) Where the joint use arrangement begins and ends.
(2) On every electric supply pole that carries a vertical pole ground wire to which are connected transformers, capacitors, or other types of power equipment that draw load current under normal conditions.

(3) If the joint use section is longer than 1/2 mile, bonds should be made to the MGN every 1/4 mile. Bonds made in accordance with item (2), if occurring at not greater than 1/4 mile intervals, may be counted as fulfilling this requirement.

6.22 Where telephone cables are supported by the same poles used for electric supply circuits of the nonmultigrounded neutral type, cable shields are grounded by means of their connections to the central office ground (provided the shield is electrically continuous) and by such other grounds as it may be desirable to place for lightning protection as described previously. On poles carrying vertical pole ground wires to which are connected transformers, capacitors, or other types of equipment that draw load currents under normal conditions, the cable suspension strand should be bonded to the vertical pole ground wire.

6.23 Vertical pole ground wires on electric supply poles interconnected to transformers or capacitor banks should be connected directly to the power system neutral. The transformers or capacitor banks should also have direct connections to the power system neutral. At such locations visual inspection from the ground should be made, before climbing, to ascertain that the vertical pole ground wire is actually connected to the neutral. If it is not connected, this fact should be reported to the power company; and the wire should be regarded as energized. The pole should not be touched or climbed by the telephone linemen until the condition has been corrected by the power company.

6.24 Where interconnection of the support strand to the multigrounded neutral is required by paragraphs 6.1 and 6.21, it should be accomplished by the appropriate method for the conditions prevailing at the pole in question as follows:

6.241

Condition	Method
Pole already equipped with a vertical pole ground wire connected to the MGN.	A ground wire assembly unit (PM2A) should be installed. A bonding conductor should be attached to vertical pole ground wire by telephone construction forces if satisfactory to the power company.
Pole not equipped with vertical ground wire.	A ground wire assembly unit (PM2A) should be installed and sufficient slack left to permit the bonding wire to be extended to and connected to the MGN if the pole in question is at the beginning or at the end of

the joint use section. Connection of the bonding wire to the MGN shall be made only by the power company. For intermediate bonds required by 6.21 (2), a pole already equipped with a pole ground wire should be selected and a ground wire assembly unit (PM2A) should be installed.

6.25 In most instances, interconnection of the cable shield to the MGN will result in a decrease in noise level of the telephone system because of the additional shielding effect provided by the neutral conductor. In a few instances the noise level could increase if excessive residual power currents flow in the shield as a result of bonding. This situation is most likely to occur if the resistance of the neutral to ground is relatively high. In such instances reduction in the number of bonds to the MGN to reduce the shield current usually will be beneficial. More information on noise in cable circuits is given in REA TE & CM-451, "Telephone Noise Measurement and Mitigation."

7. MISCELLANEOUS SITUATIONS

7.1 Underground or Buried Cable Dips in Aerial Cable Runs - No protection is needed at the junctions of aerial cable (either plastic- or paper-insulated) and short underground or buried plastic-sheathed cable dips in aerial cable runs.

7.2 Protection at Loading Points - The dielectric strength of loading coils approved for REA use is such that no supplementary protection is required in addition to the measures recommended herein for protection of the associated cable.

7.3 Buffer Protection - Where a good shield ground such as a MGN of approximately 25 ohms or less cannot be obtained at or within 200 feet of a cable-non-cable junction, the beneficial effect of such a ground may be achieved by placing buffer protection in the form of yellow coded arresters between the non-cable pairs and ground at a point about 1500 feet (± 1000 feet) from the junction, provided a ground of approximately 25 ohms or less can be obtained at that point.

7.4 Pole Lightning Protection Wires - Lightning protection wires may be necessary to prevent the splitting of wood poles used for cable supports in certain areas of high lightning incidence and severe exposures. A study of local conditions should be made by the borrower's engineer to determine to what extent this protection is required. Normally, extensive use of lightning protection wires should be necessary in the shaded areas of the map on Figure 1 and in unshaded areas which have more than 60

lightning storm days per year. In systems within these areas and where local experience in other areas clearly indicates the need, lightning protection wires should be installed on poles which are severely exposed due to being on or near the top of a hill with little or no shielding such as buildings, trees, or a higher foreign pole line. In such hilly areas it is desirable to install protection wires on a number of consecutive poles. With flat terrain where the exposure is more uniform and less severe, protection wires should be installed on every third or fourth pole. In the unshaded areas of the map (Figure 1), which have less than 30 lightning storm days per year, pole lightning wires are not considered necessary.

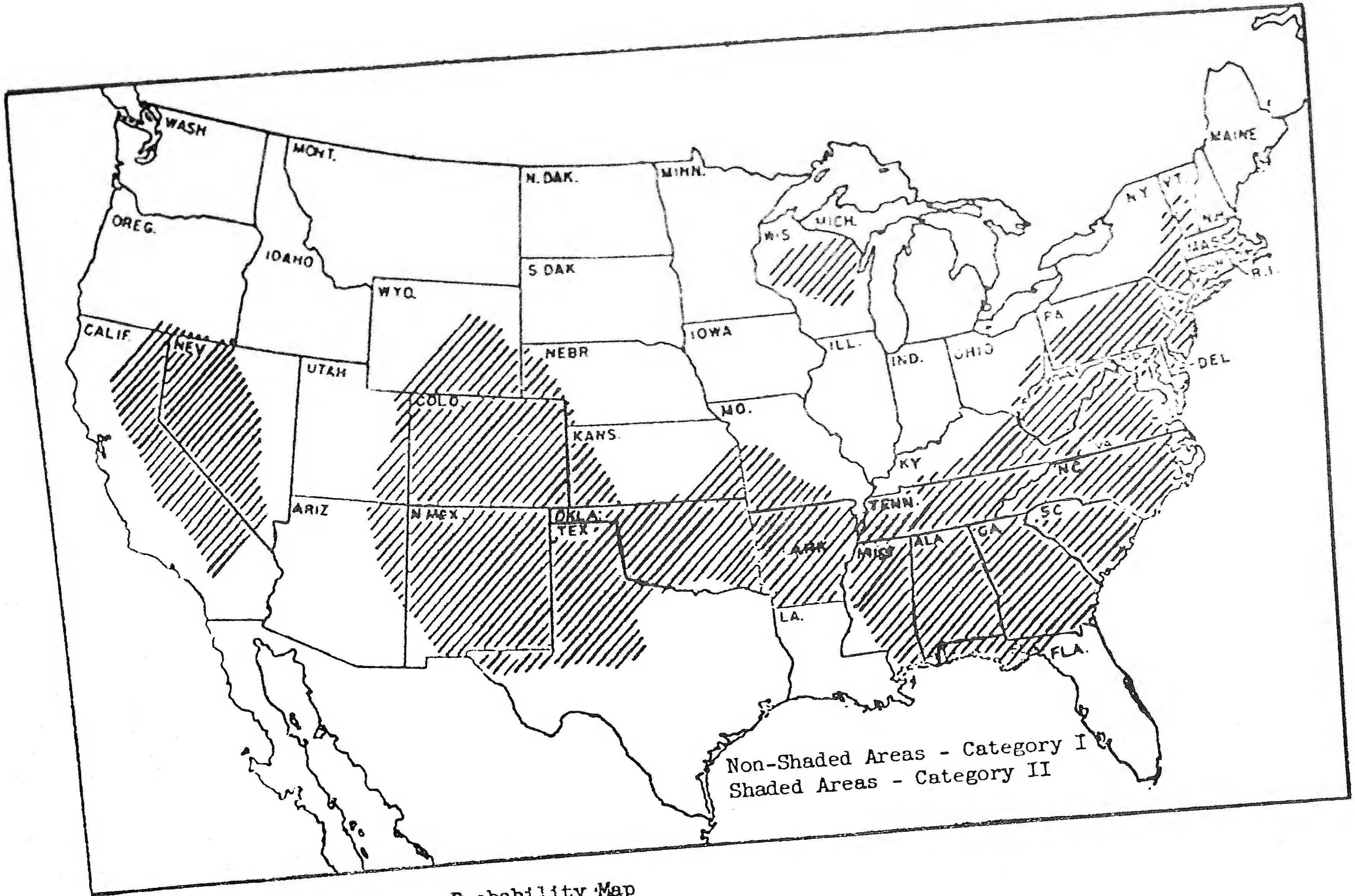

Fig. 1 - Lightning Damage Probability Map